IRON TRANSPORT AND REMOVAL DYNAMICS IN THE OXIDATIVE UNITS OF A PASSIVE TREATMENT SYSTEM

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ASMR2017: What's Next for Reclamation

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Average System Influent Water Quality (3 seeps)

n= 40 2004-2008 pre system construction

Component	Concentration
Iron	191.0 ± 10 mg/L
Zinc	9.65 ± 1.0 mg/L
Manganese	1.60 ± 0.1 mg/L
Lead	62 ± 13 µg/L
Cadmium	15 ± 5 µg/L

- Q varies seasonally
  400-700 L\min annually
- Influent pH
  5.95 ±0.06
- Net Alkaline
  393 ± 13 mg\L $CaCO_3$

Understanding Iron Chemistry

- Iron removal and storage within oxidative cells is based on two distinct processes:

- **Iron Oxidation** – Fe^{2+} oxidized to Fe^{3+}

$$4Fe^{2+} + O_2 + 4H^+ \rightarrow 4Fe^{3+} + 2H_20$$

- **Iron Hydrolysis**: Iron Precipitation

$$Fe^{3+} + 3H_20 \rightarrow Fe(OH)_{3(s)} + 3H^+$$

Oxidation is the rate determining step.

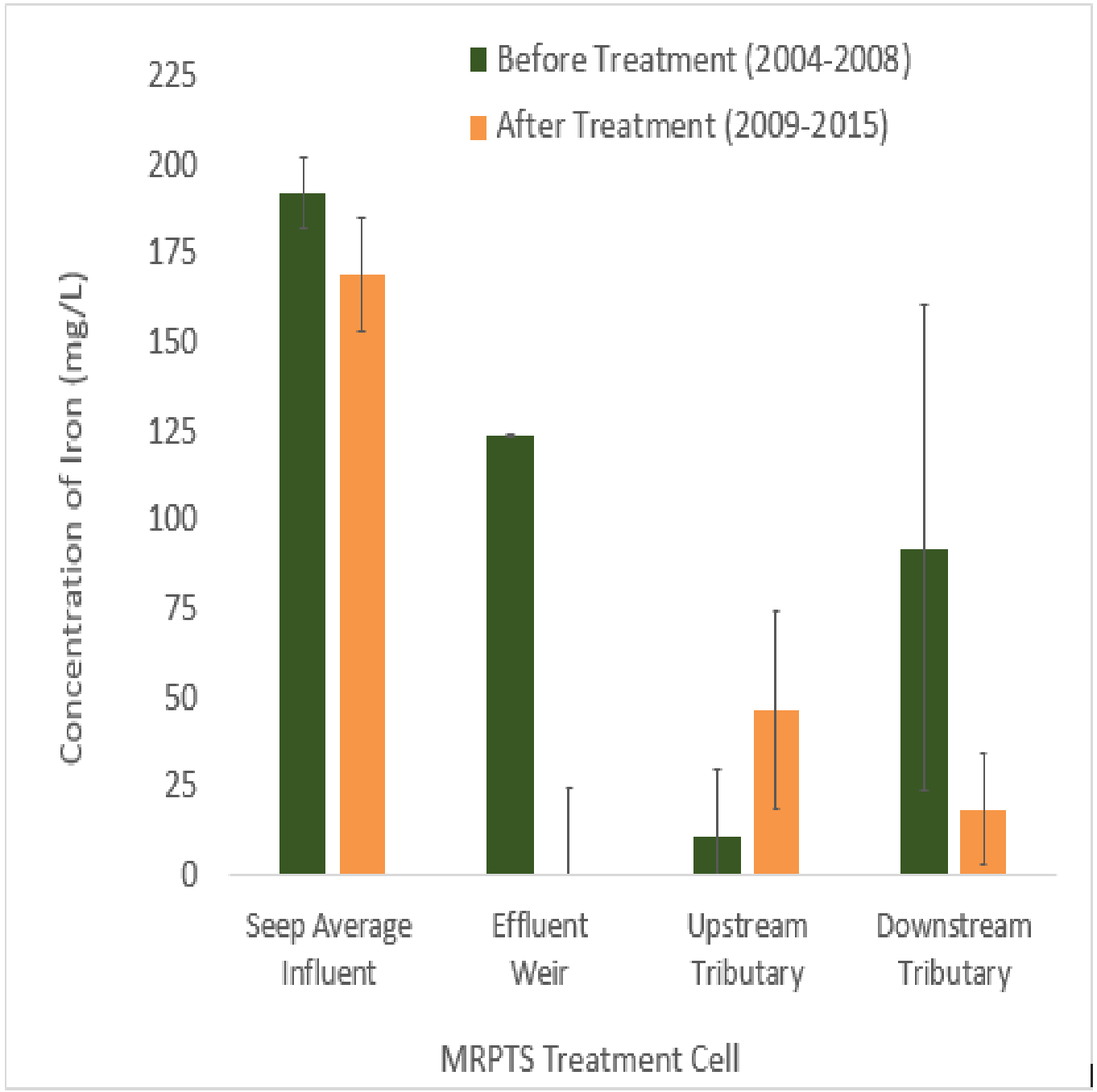
Rate influenced by iron concentration, pH, dissolved oxygen, and temperature.

MRPTS Improves Water Quality of Tributary

Tributary Fe Loading

Before System Installation:
71.3 kg Fe/day average

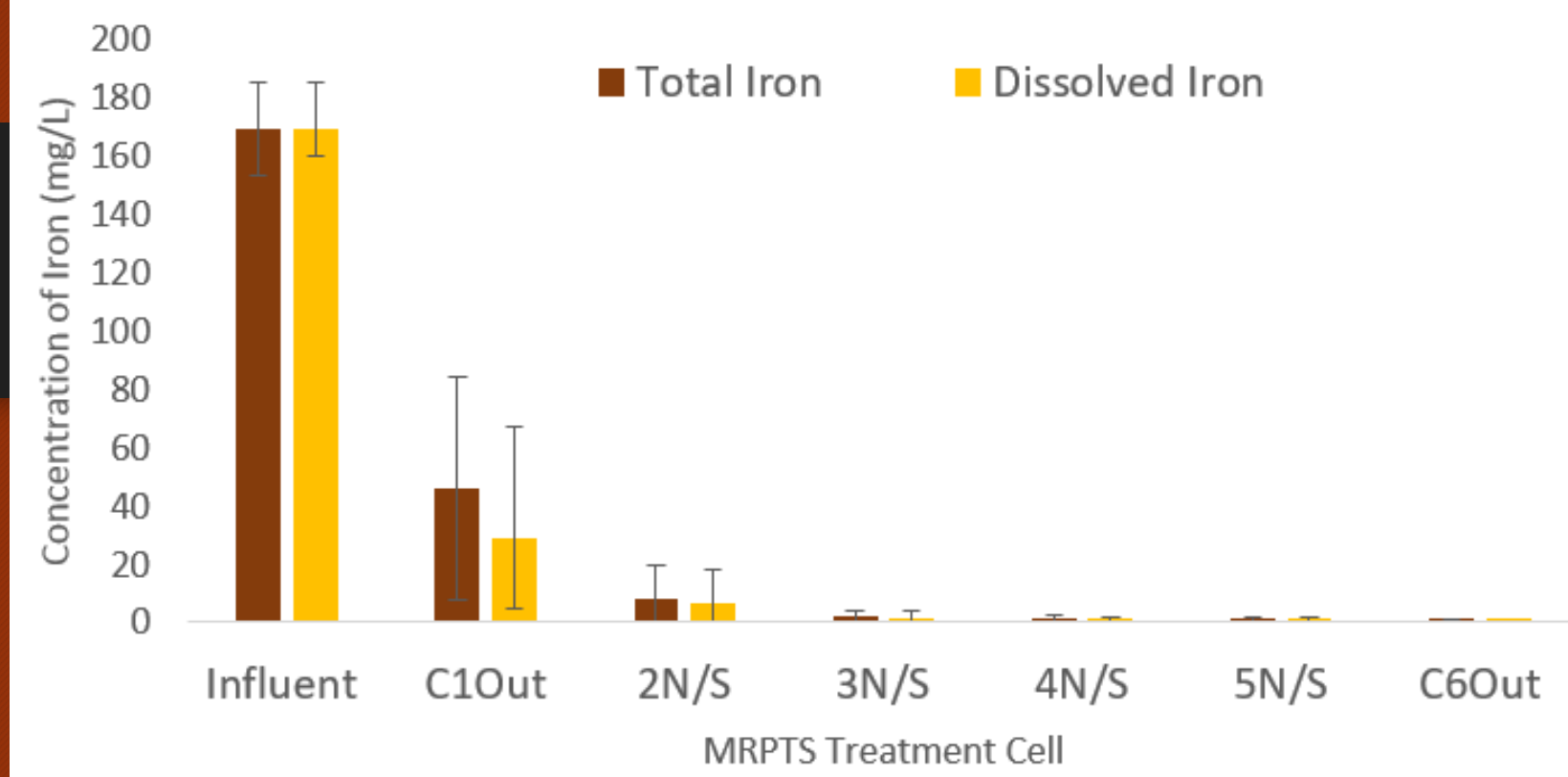
After System Installation:
0.30 kg Fe/day



MRPTS Fe Removal

Oxidative Unit

- Cell 1
  - Removes 87 kg/day
- Cell 2S/SN
  - Removes 17.3 kg/day



Iron Removal Efficiency Profiling

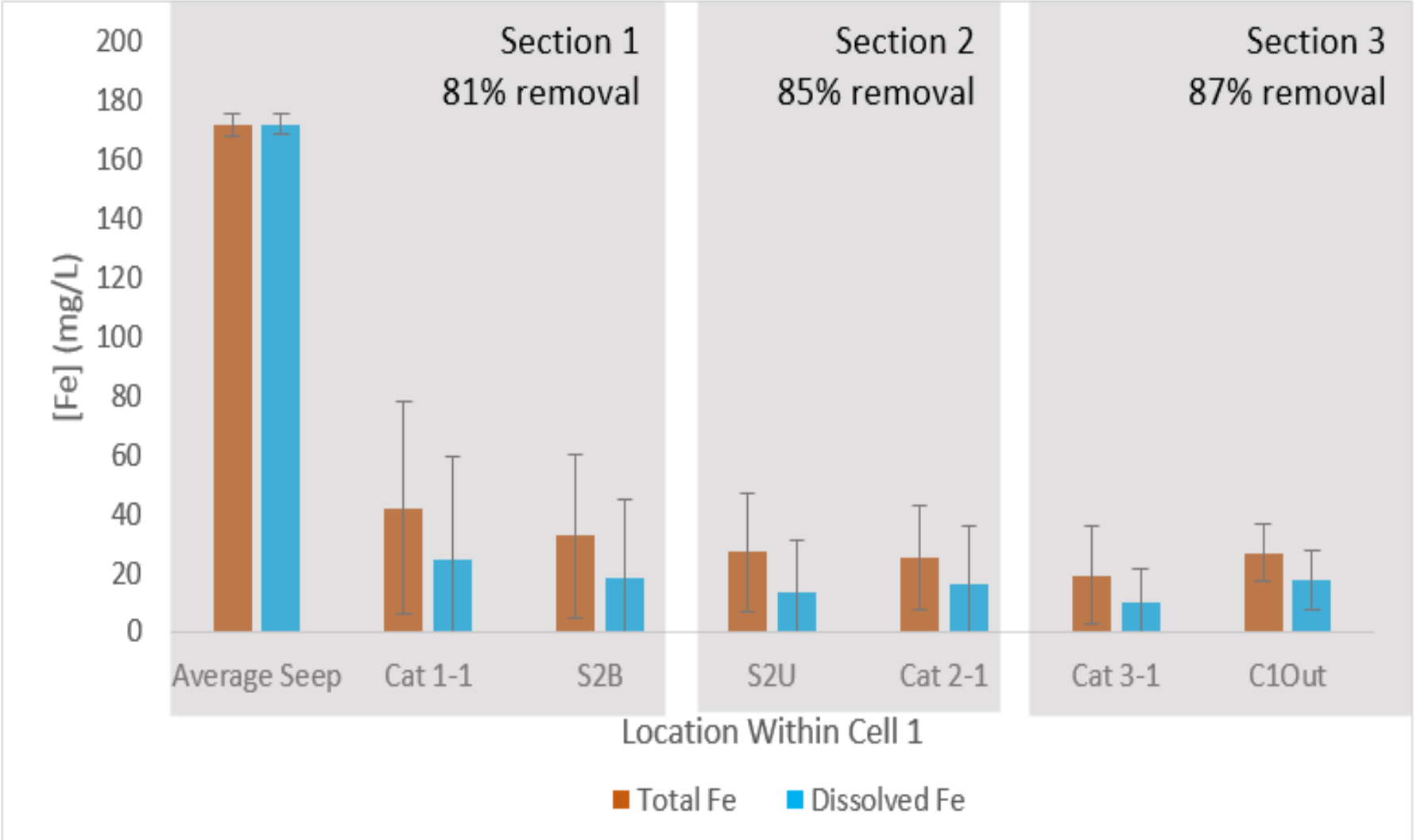
- To determine the spatial distribution of iron removal, sedimentation, and storage over time.

- Provides essential insight into how the design of the treatment cell may be refined to optimize processes favoring iron removal enhancement.
  - existing design
  - design of future passive treatment systems

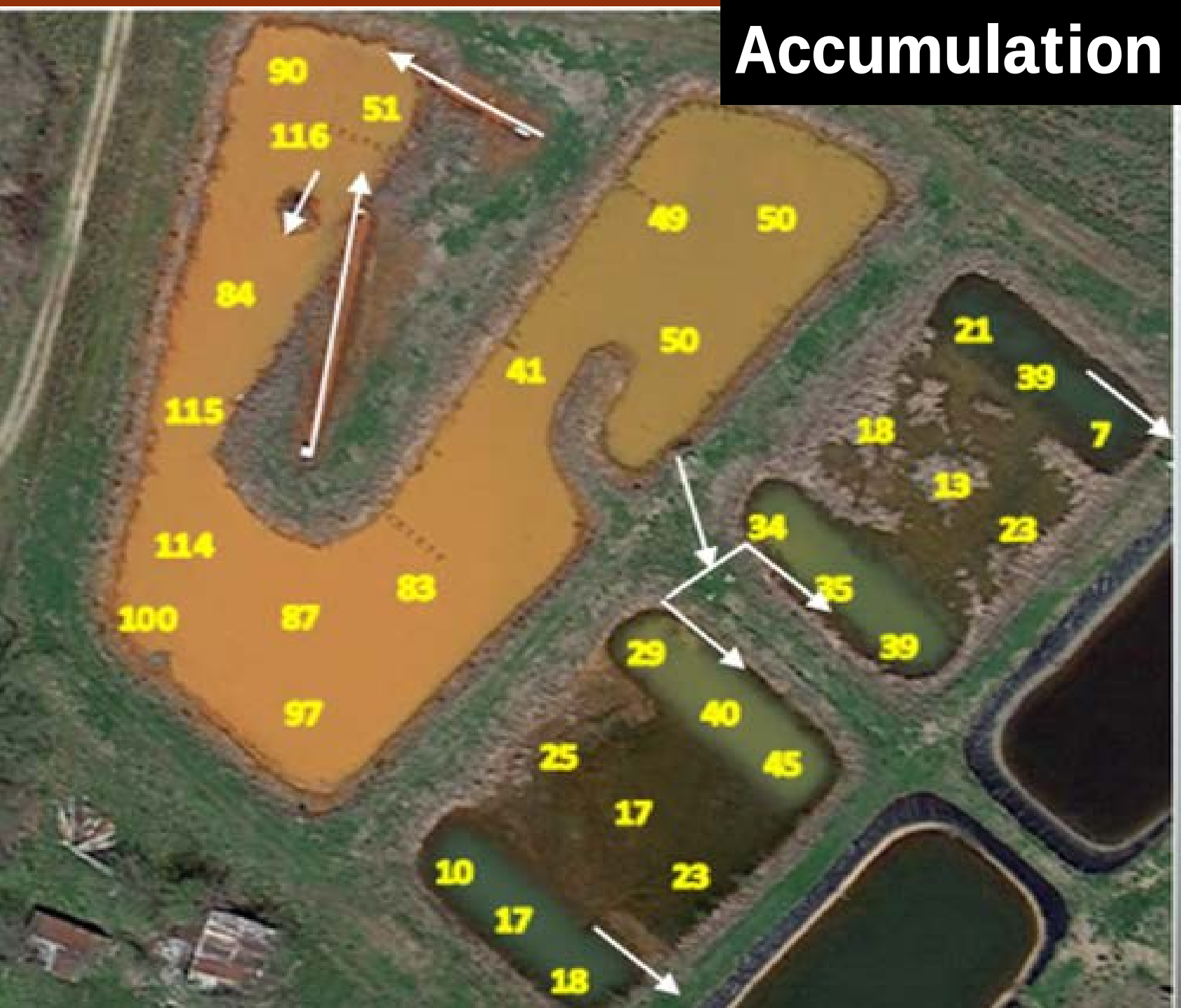
Building Progressive Removal Profile:

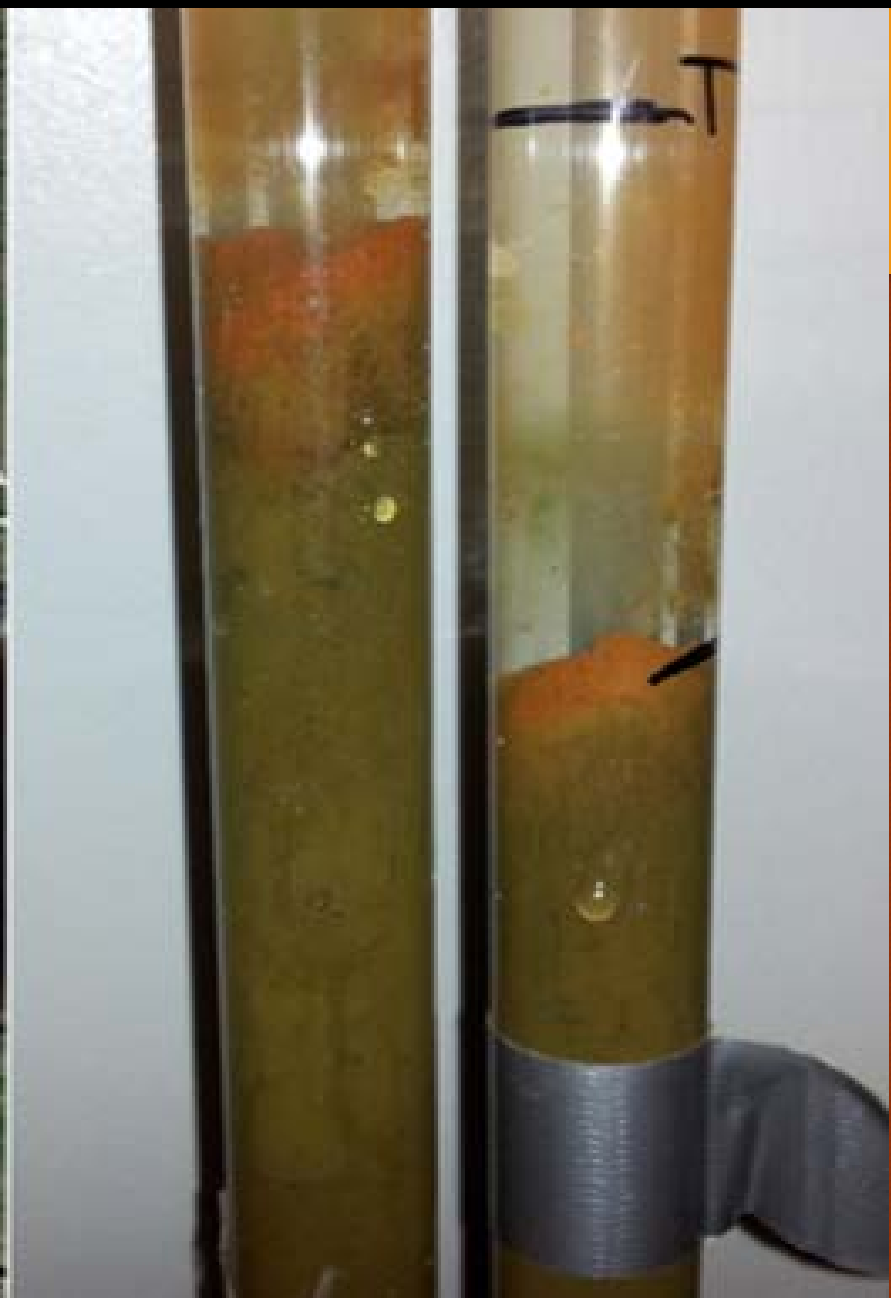
- Horizontal Component
  - Sample locations with increasing distance (time) from influent
- Vertical Component
  - Sample locations with increasing depth from surface
- Temporal Component
  - Sample collection with increasing time (seasonal, annual, 3-5 years)

Progressive Iron Removal Dynamics

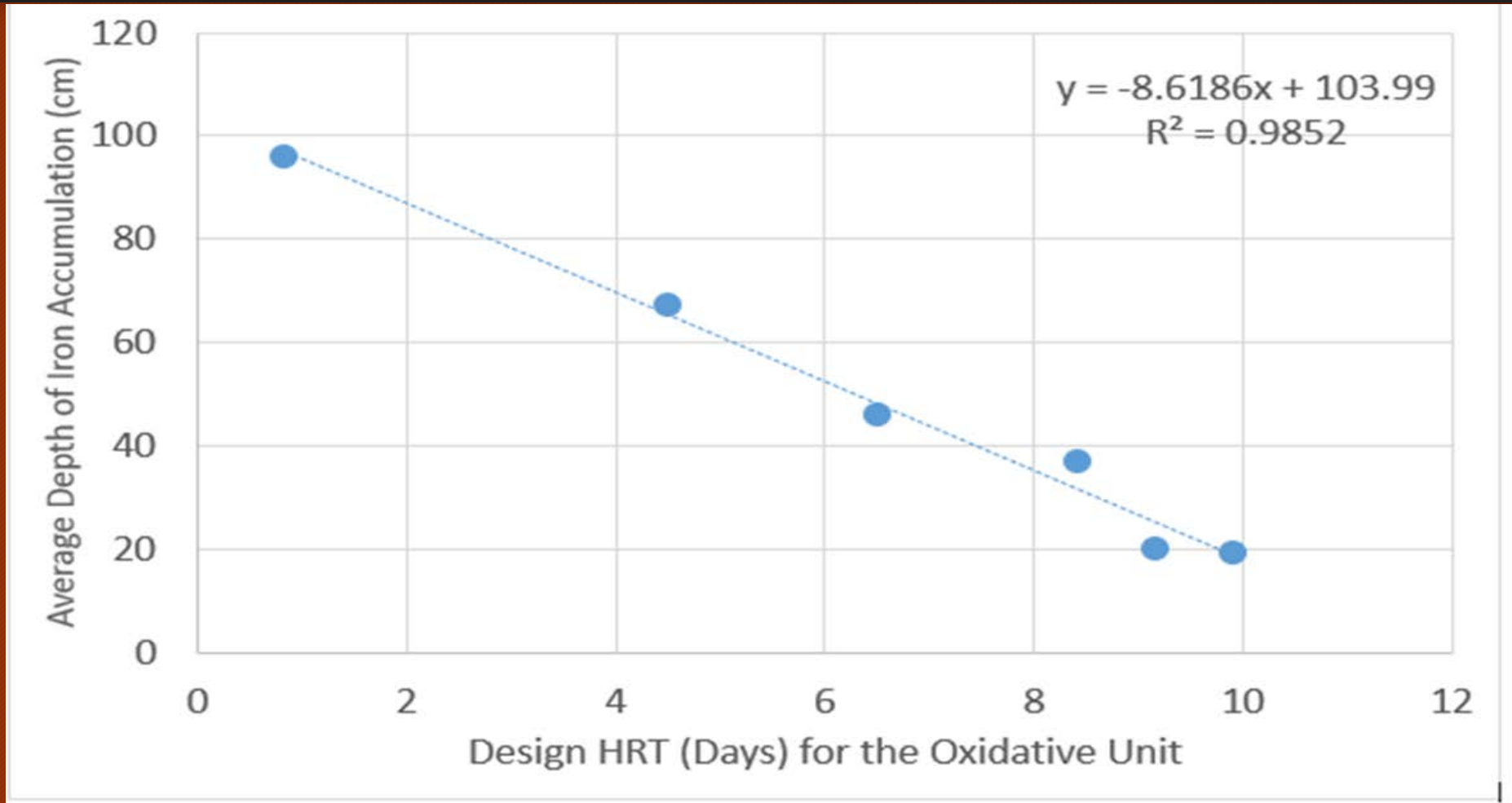


Accumulation of Fe (2008-2015)





Average Accumulation Depth Decreases With Increasing HRT within The Oxidative Unit



Solids Characterization

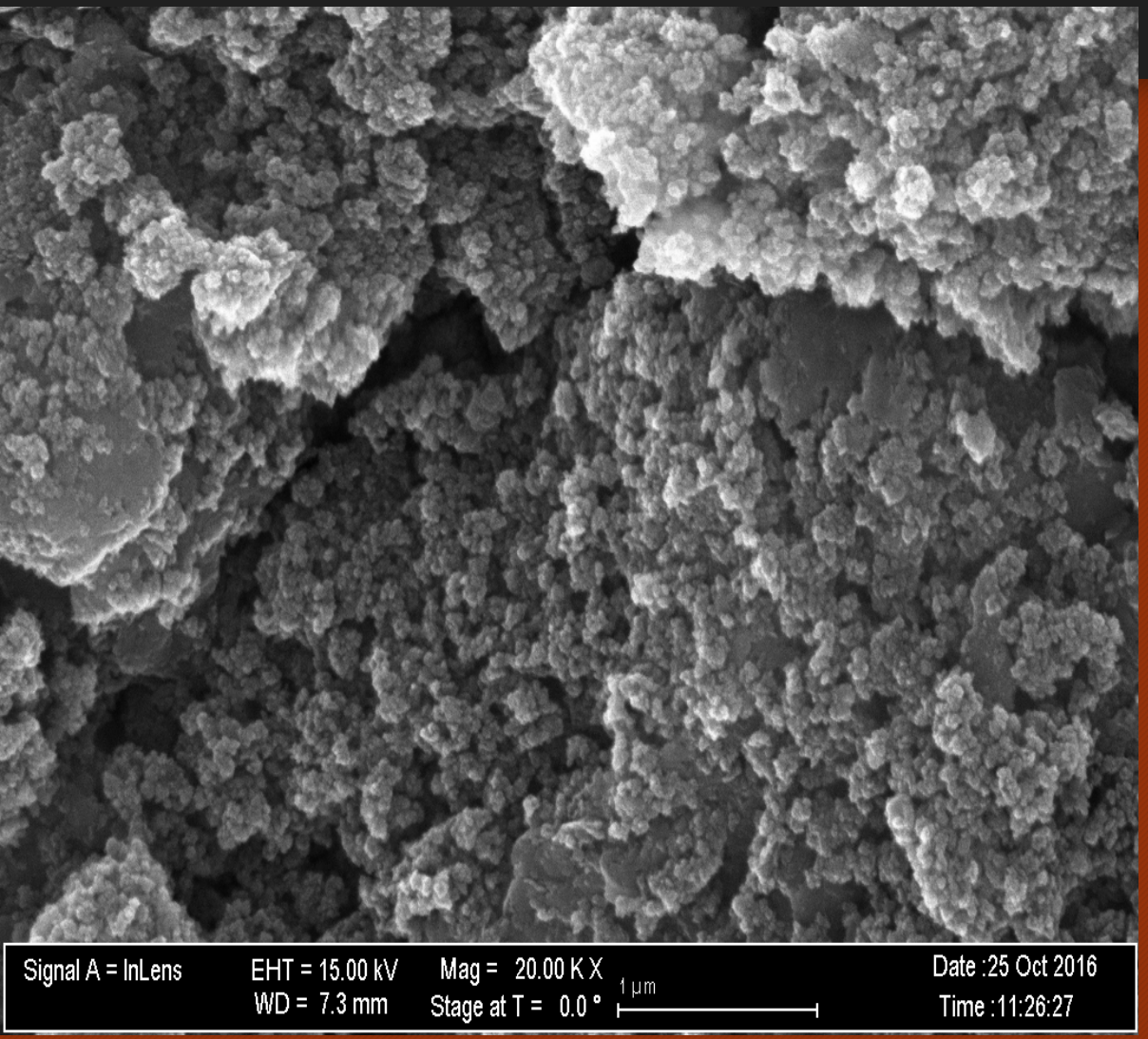
- Increased with HRT:
- Particle size Crystallinity

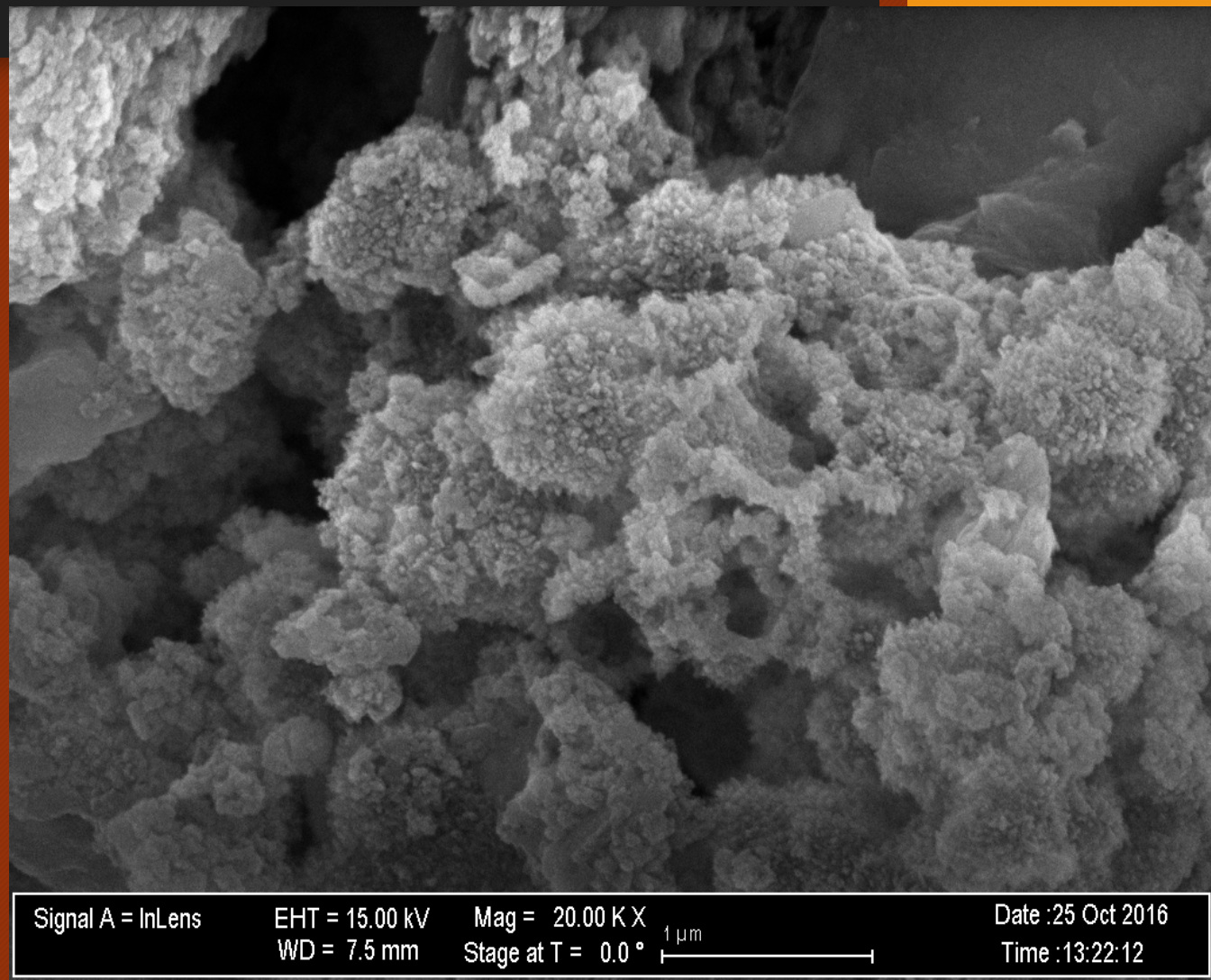
- Only crystallinity increased with increasing depth

	Top (Newest) $FeOOH_{(s)}$			Bottom (Oldest) $FeOOH_{(s)}$		
	Mean Size (µm)	D60/D10	SA (cm^2)	Mean Size (µm)	D60/D10	SA (cm^2)
Cell 1	12.51±3.35	15.98±1.78	0.61±0.07	10.80±0.06	12.62±1.09	0.58±0.02
Cell 2N	18.84±5.26	12.60±1.55	0.44±0.10	18.18±3.57	10.23±0.50	0.40±0.08

	Top (Newest) $FeOOH_{(s)}$			Bottom (Oldest) $FeOOH_{(s)}$		
	Residual Moisture (%)	LOI Organic Matter (%)	Crystallinity (%)	Residual Moisture (%)	LOI Organic Matter (%)	Crystallinity (%)
Cell 1	1.6±0.2	3.4±1.6	18.7±0.2	0.9±0.1	5.2±3.1	16.0±0.01
Cell 2N	0.8±0.2	2.4±1.8	60.0±0.5	0.6±0.2	1.8±1.0	73.3±0.3

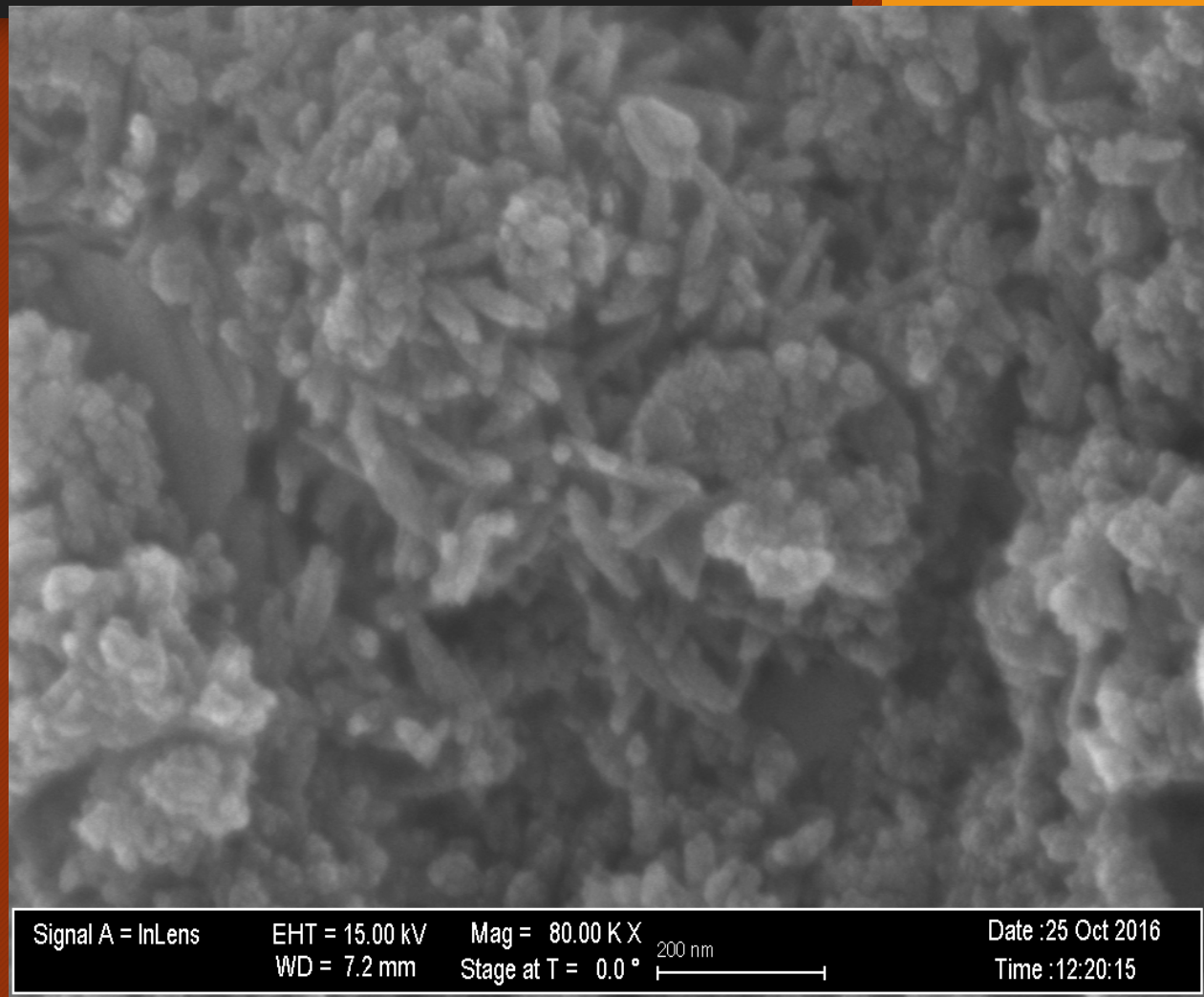
Amorphous vs Crystalline





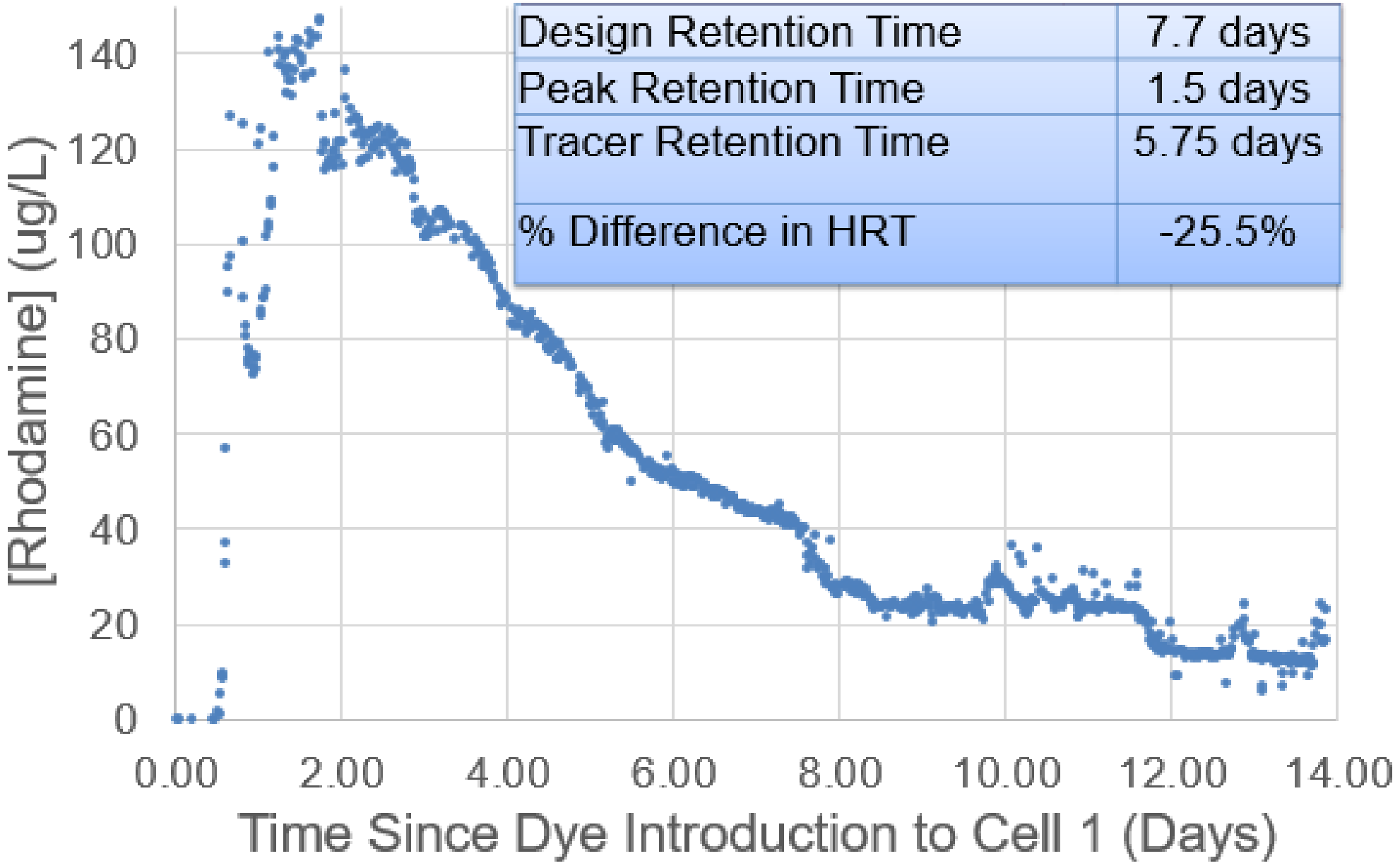
Crystalline Goethite Formation

- Orthorhombic crystals observed in SEM
- RAMAN microscopy verified as Goethite
  - Principle mineral phase



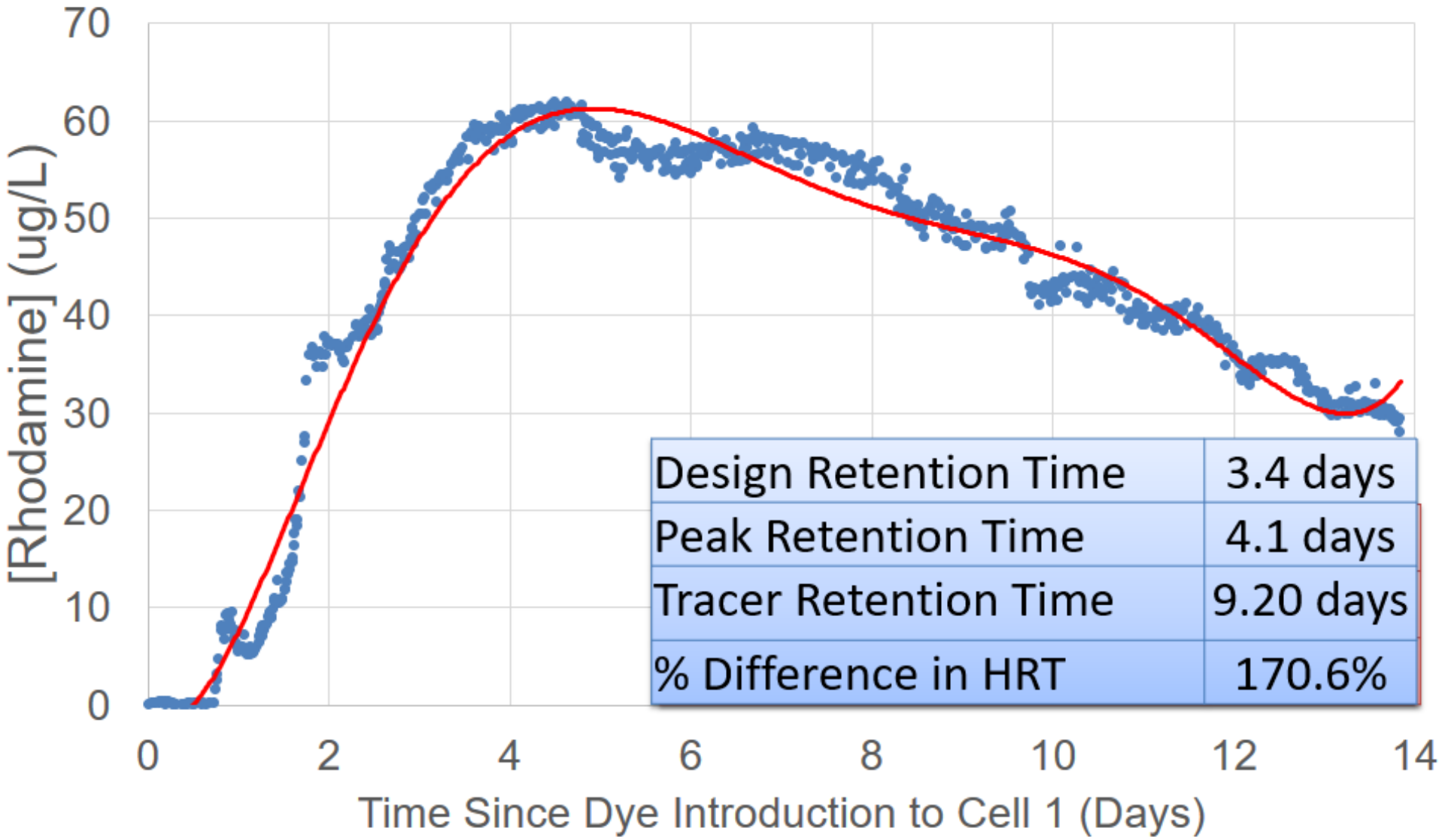
Solids Accumulation Inspires Rhodamine Tracer Study (2009-2015)

C1Out Rhodamine Transport Profile



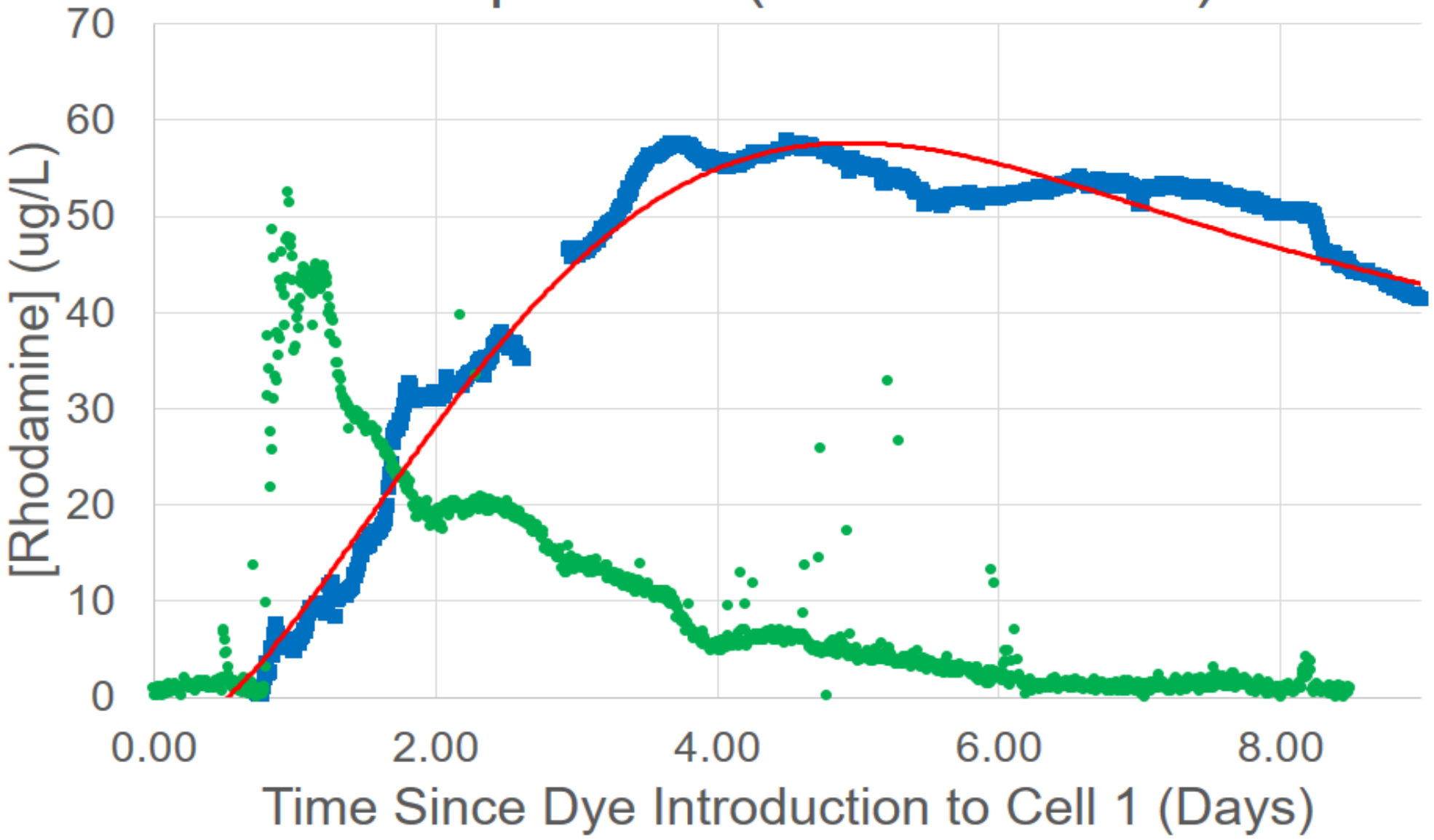
Design Retention Time	7.7 days
Peak Retention Time	1.5 days
Tracer Retention Time	5.75 days
% Difference in HRT	-25.5%

C2Nout Rhodamine Transport Profile



Design Retention Time	3.4 days
Peak Retention Time	4.1 days
Tracer Retention Time	9.20 days
% Difference in HRT	170.6%

C2Out Rhodamine Transport Profile Comparison (2015 vs 2009)



	Cell 1	Cell 2N	Cell 2S
Area Adjusted Iron Loading ($g/m^2/day$)	24.4	11.5	11.6
Mean Iron Removal Efficiency (%)	78	82	82
Mass of Iron Removed (kg/day)	87	17.3	17.3
Area Adjusted Removal Rate ($g/m^2/day$)	19.0	11.5	11.6
Peak Residence Time (days)	1.5	4.3	3.7
70% Residence Time (days)	5.75	9.2	9.0
Design HRT (days)	7.7	3.5	3.5
Change in HRT from Design (days)	-2.0	+5.7*	+5.5*

*due to poor hydraulic conductivity and high storm activity impairing transport through the system

Significance of Work

- Iron oxyhydroxide precipitates formed from the oxidation and hydrolysis of Fe^{2+} accumulate within the preliminary oxidation cell (Cell 1) and the surface flow wetlands (Cells 2N/2S) of MRPTS.

- The accumulation of iron oxyhydroxides is not uniformly distributed within each cell, with the first section of the cell favoring deeper deposits of material.

- Thus far, performance has not been inhibited by solids accumulation, but hydraulic conductivity of Cells 3N/3S impact HRT and water levels in the oxidative unit.

Comments / Questions?